ITP Corporate Peer Review: Glass Subprogram

March 9, 2004

Panel Members

- **Elliott Levine, U.S. Department of Energy**
  - ITP Glass Technology Manager and Glass Industry Liaison
- **Dr. Warren Wolf, Consultant**
  - Former Vice President, Science and Technology at Owens Corning (retired)
- **David Rue, Gas Technology Institute**
  - Manager, Industrial Combustion Processes
- **Daniel Wishnick, Eclipse Inc.**
  - Group Vice President

Key Presentation Contents

- The structure of the industry, the barriers it faces and how these barriers influence our approach
- Why energy matters greatly to the industry
- The types of analyses that guide our efforts
- The management and control processes we use
- The successful collaborations and partnerships we have with the glass industry
- The types of results and leverage that we are achieving

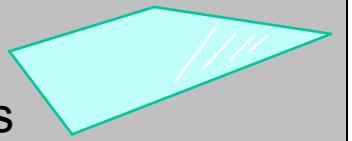
Glass Industry: Four Major Sectors

Container

9.5 million tons
80 trillion Btu
$4.2 billion sales

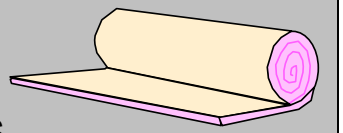
Flat

5.3 million tons
63 trillion Btu
$2.7 billion sales



Fiber

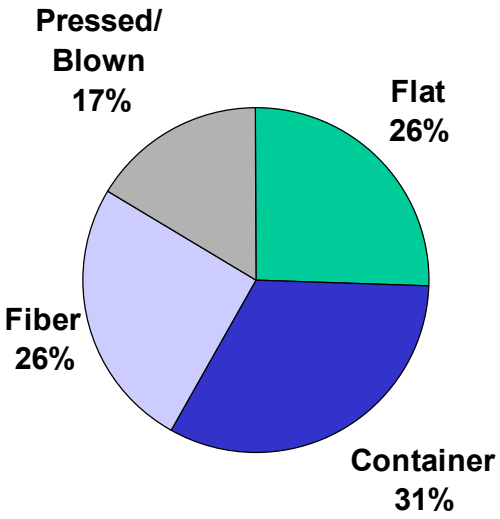
3.0 million tons
63 trillion Btu
$4.8 billion sales



Pressed/Blown (Specialty)

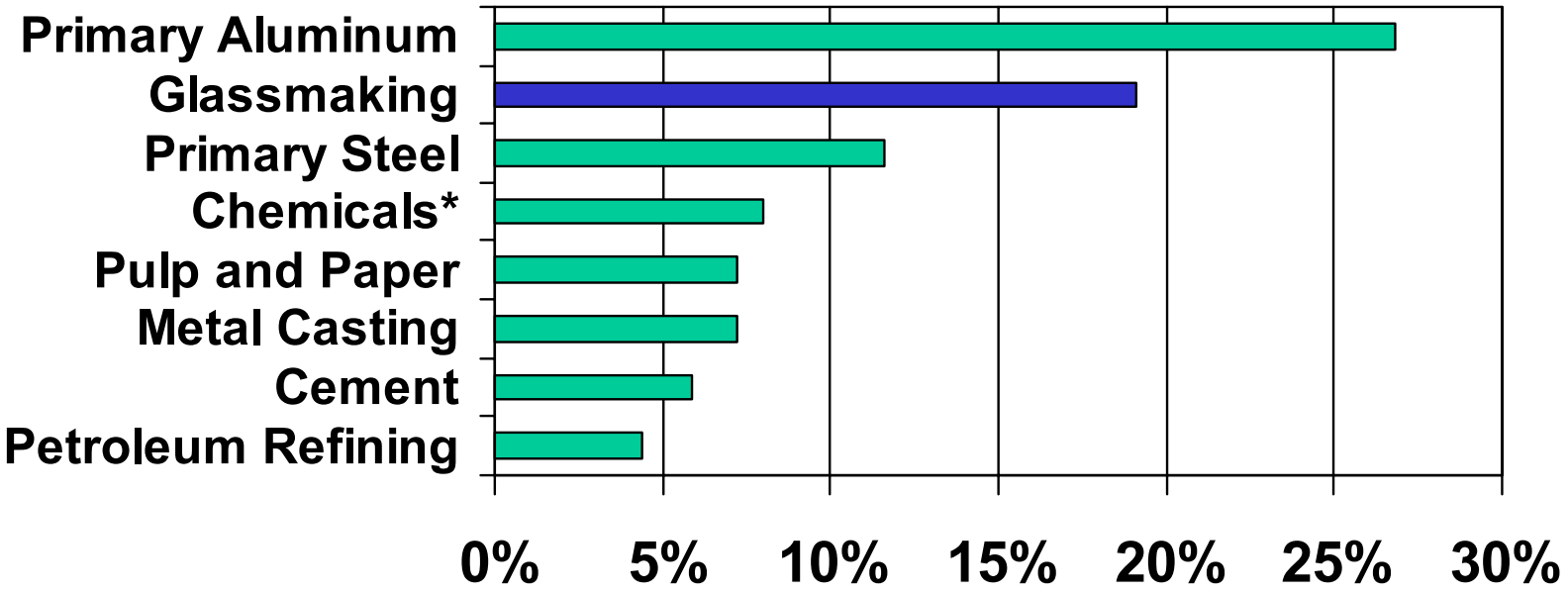
2.5 million tons
41 trillion Btu
$5.2 billion sales

Energy Use by Sector



Glass: An Energy-Intensive Industry

Purchased Energy for Heat and Power: Estimated Share of Direct Production Costs, 2001



* Excludes pharmaceuticals

Data derived from 2001 Annual Survey of Manufactures, Department of Commerce

The U.S. Glass Industry

- Around 150 major plants across the country

- Consolidation continuing, operations being conducted on a global stage

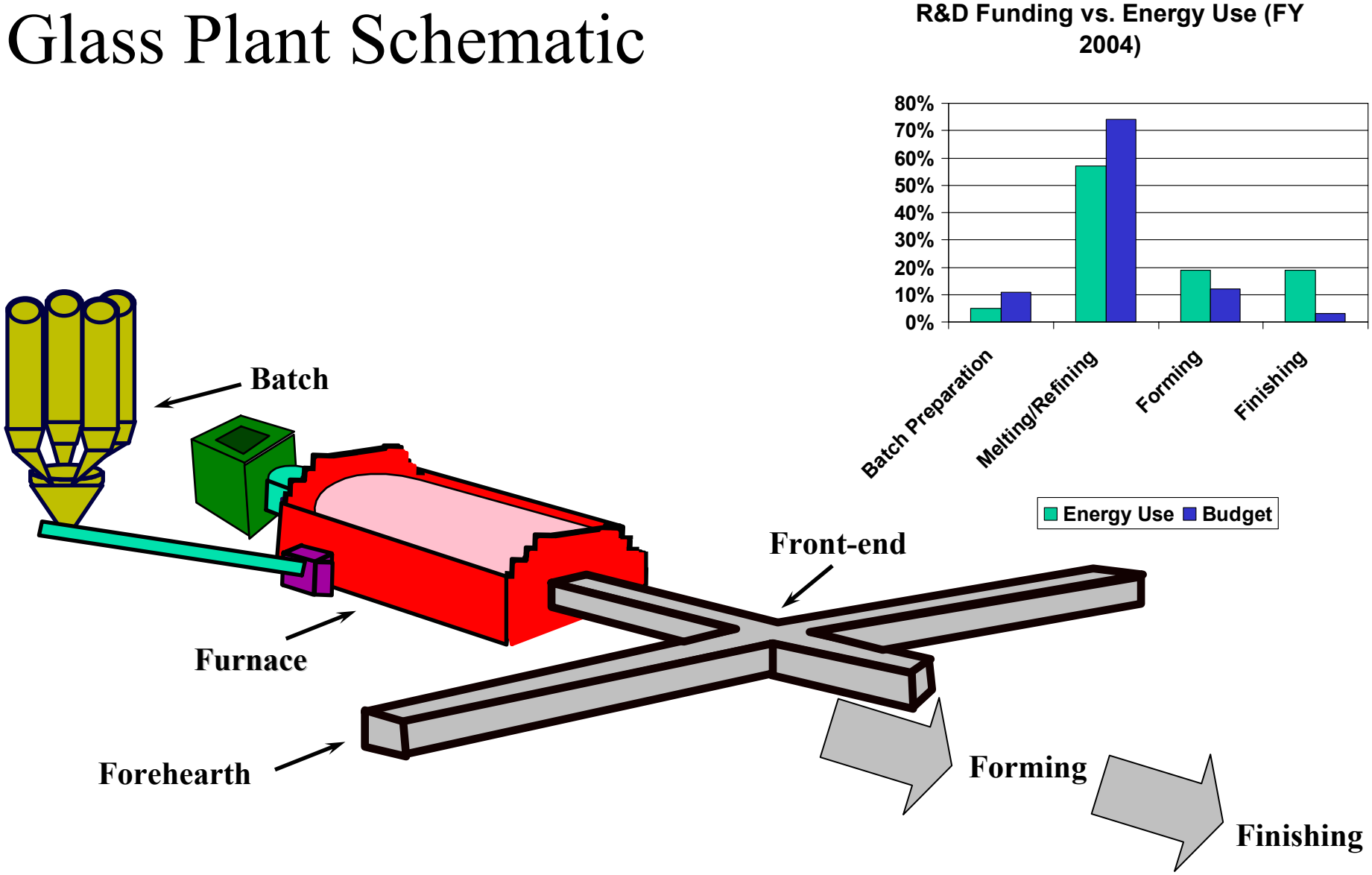
- Few resources to invest in R&D, particularly revolutionary process technologies (in-house R&D smaller or closed)

- Significant improvements in energy efficiency since 1970

Glass Processing and Technology

- In 1950s, U.S. was the world leader in glass technology
- Historical lack of collaboration due to legal concerns stemming from prior industry breakup for anti-trust reasons
- Individual company attempts to develop revolutionary technologies in response to 1970s energy crisis largely failed
- Prime opportunity for collaborative government-industry partnership

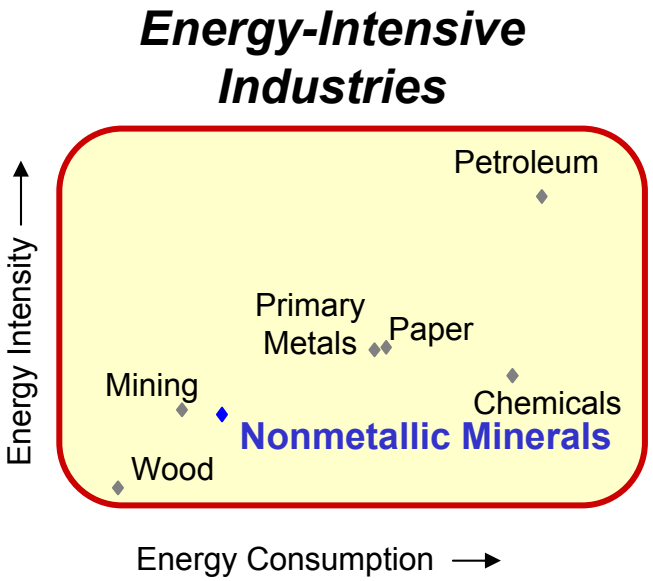
Glass Plant Schematic



EERE/ITP Mission and Goals Guide the Glass Subprogram

EERE/ITP

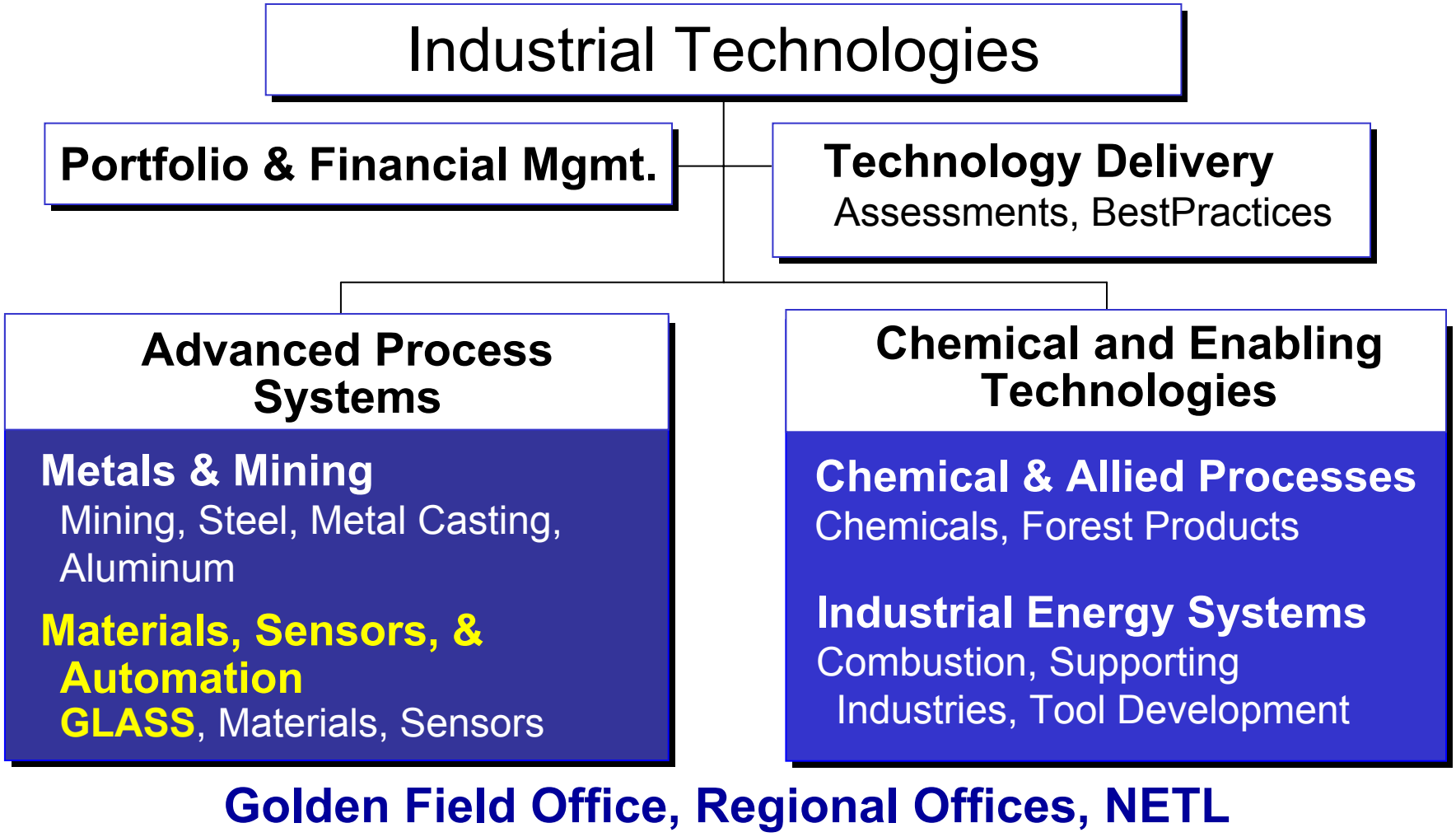
- EERE:
  Increase the energy efficiency of industry
- ITP:
  By 2020, contribute to a 30% decrease in the energy intensity of energy-intensive industries



Glass Subprogram

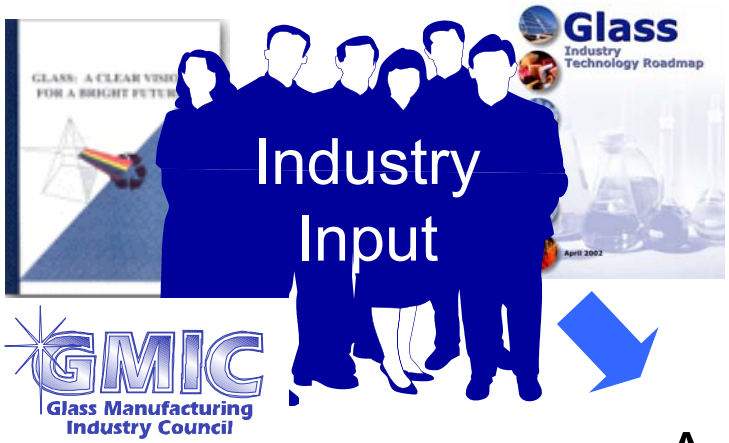
- Reduce the energy intensity of melting glass
- Improve glass industry productivity and reduce yield losses
- Leverage funding with other ITP and EERE programs

ITP Program Structure



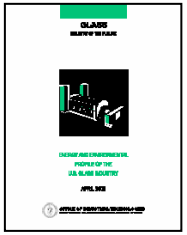
Golden Field Office, Regional Offices, NETL

Subprogram Planning Inputs and Approach



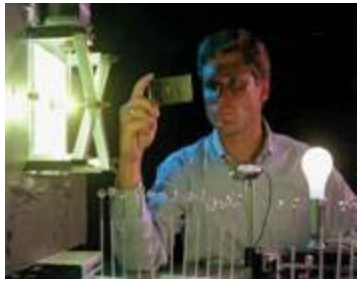
ITP
Strategic
Plan

Analytic
Studies

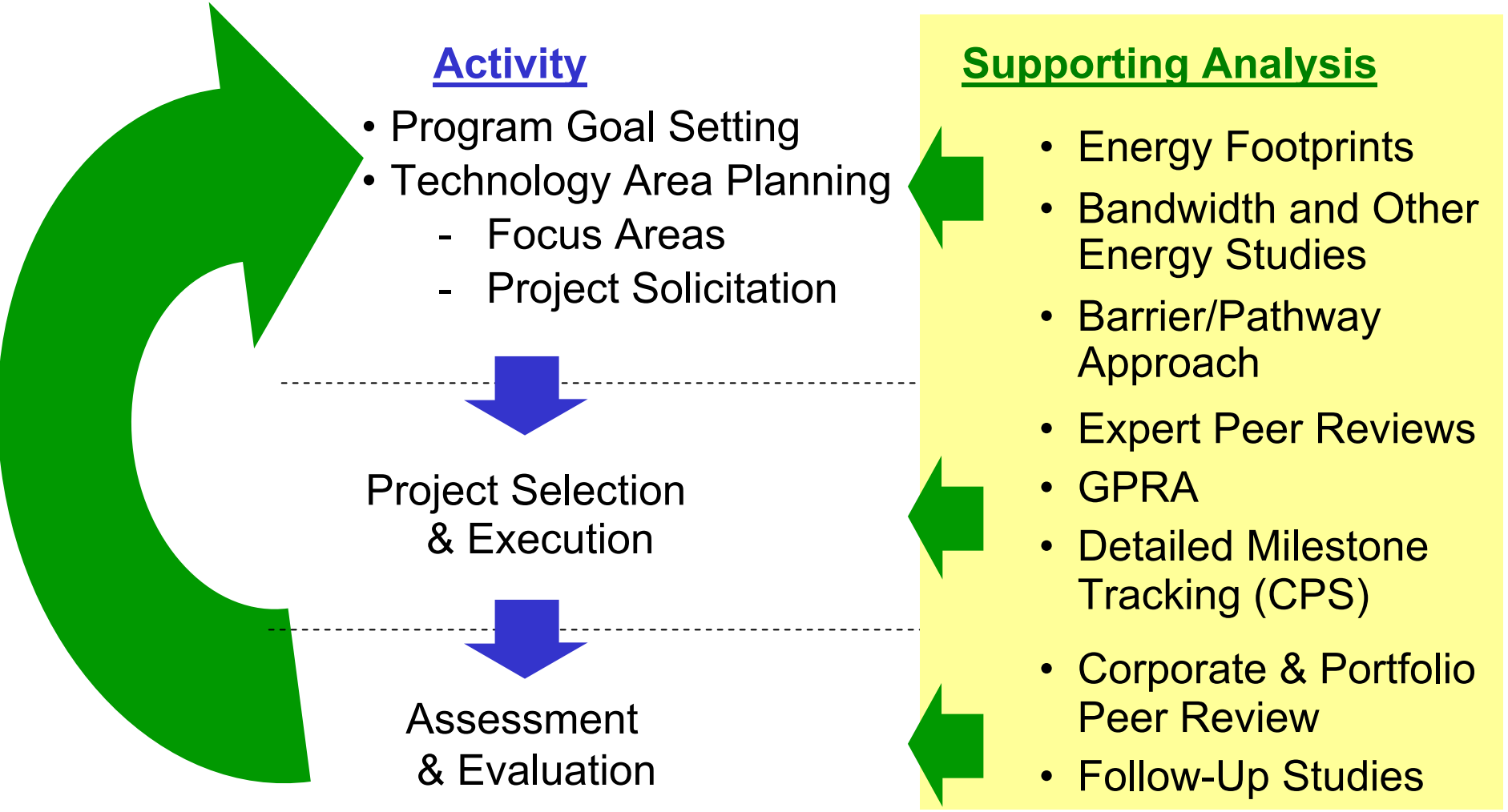


Prioritized Focus Areas

Barriers/R&D Pathways



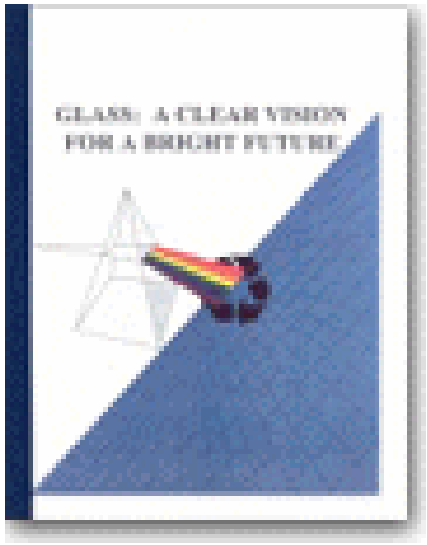
Analysis-Guided Planning



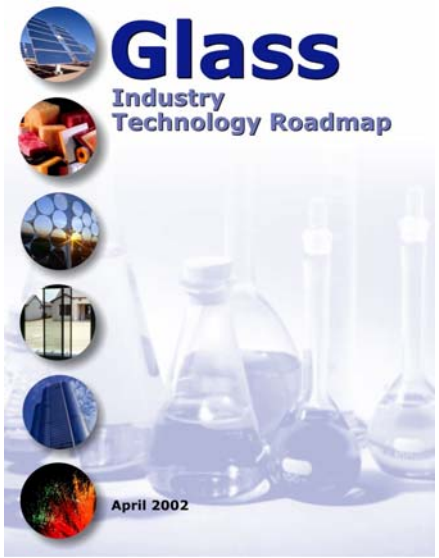
Industry Inputs

- *Glass Industry Vision*
  - Published 1996
  - Identifies industry goals and priorities

    By 2020, reduce the gap between actual and theoretical energy use by 50%



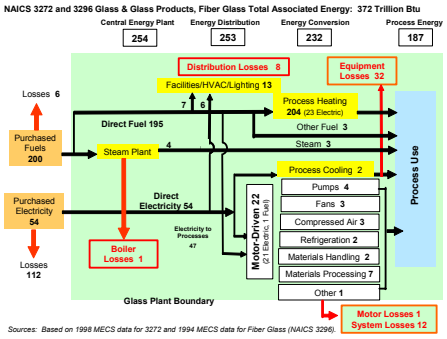
- *Glass Industry Technology Roadmap*
  - Published 2002
  - Identifies technical barriers and priority research needs in four technical areas
    - Production Efficiency
    - Energy Efficiency
    - Environmental Performance
    - Innovative Uses



- Technology Workshops

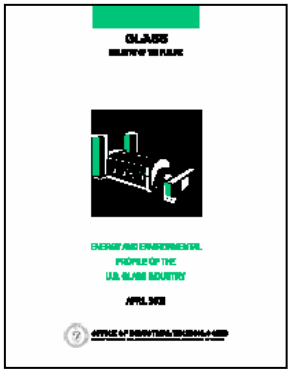
Analytic Tools and Resources for Glass Subprogram Planning

EIA MECS data
DOC Census data



Energy Footprint Analysis

Glass Industry Energy and Environmental Profile



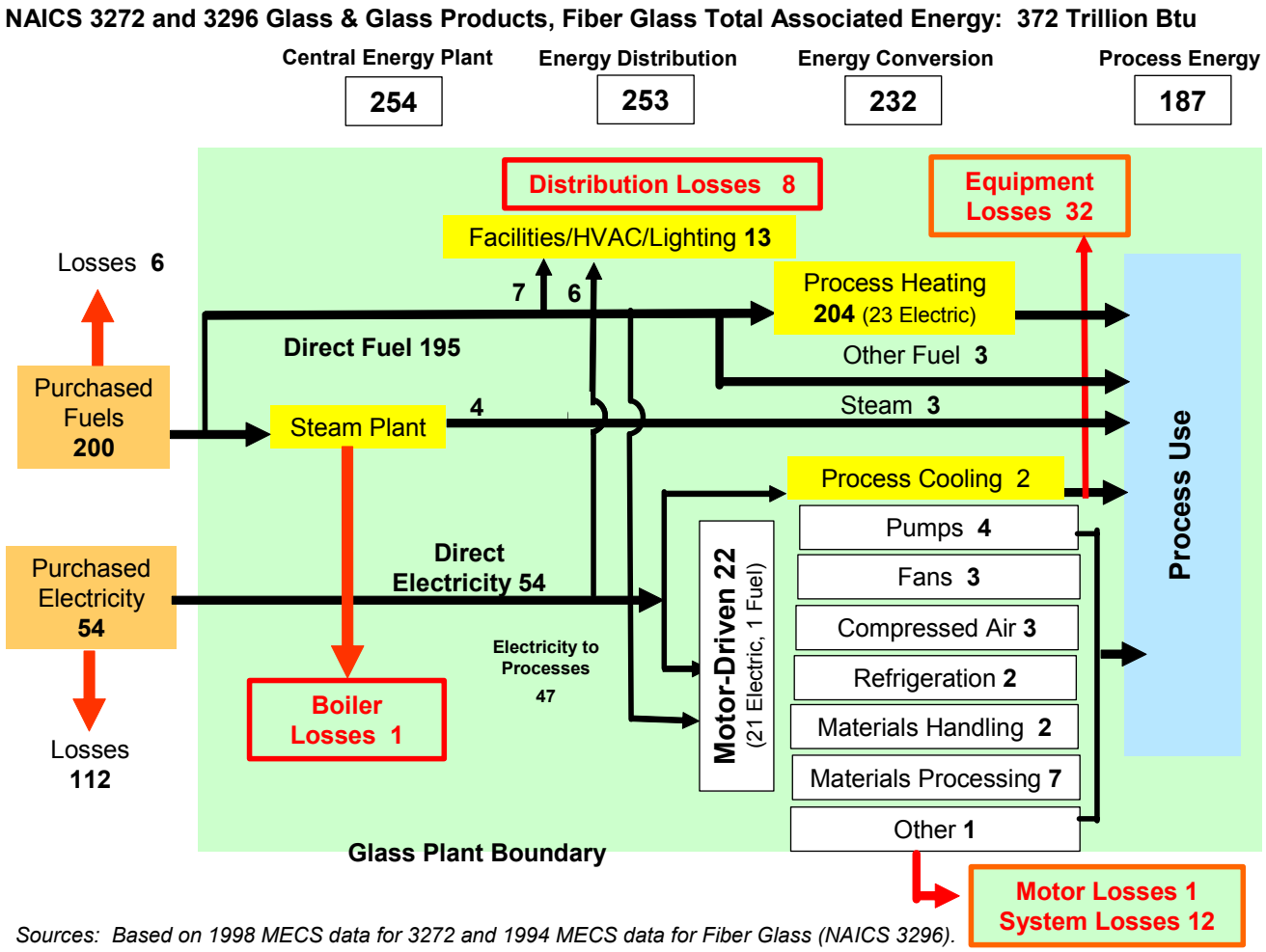
Energy Bandwidth Analysis (under development)

Technical and Economic Assessment (draft)

Bandwidth Study (under development)

Technical and Economic Assessment for Advanced Glass Melting Technologies (draft)

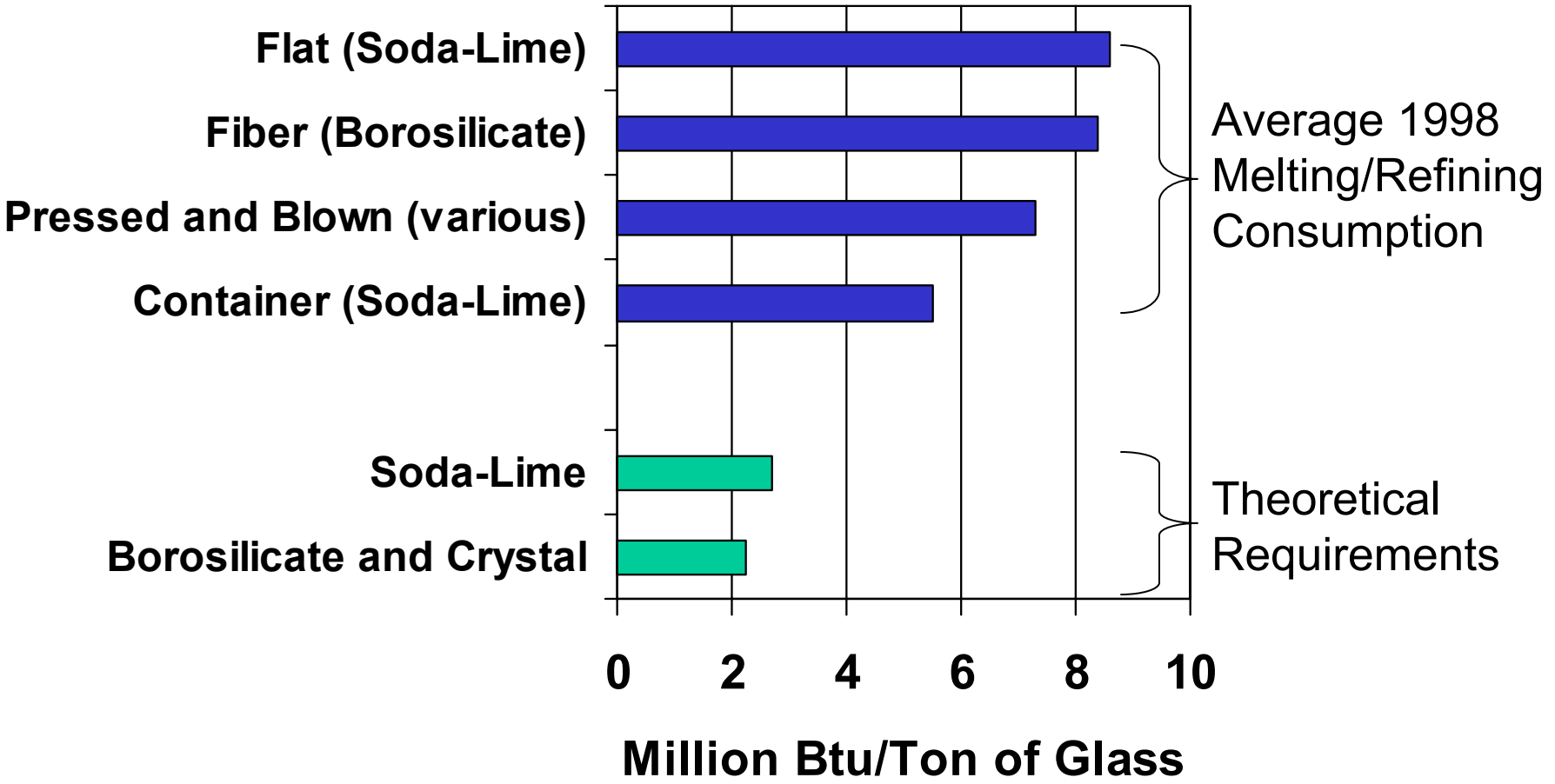
Glass Industry Footprint Analysis



Sources: Based on 1998 MECS data for 3272 and 1994 MECS data for Fiber Glass (NAICS 3296).

- Evaluates end-use and loss patterns to clarify best opportunities for energy efficiency improvements
- Losses occur in equipment and distribution systems supplying energy to process operations or converting energy to usable work

Theoretical and Average Melting Requirements



Glass furnaces use significantly more energy than theory requires

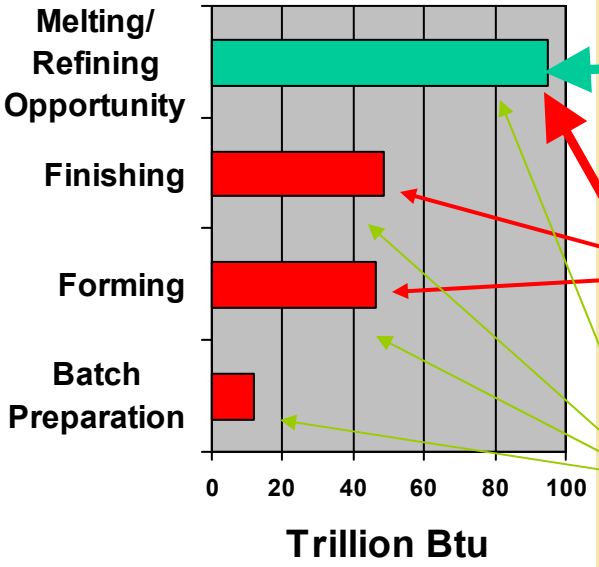
Key Variables Affecting Glass Energy Use

	Variable	Energy	Driver
Melter	Larger size	Lower	Market
	Longer campaign	Higher	Operations, safety
	Better refractory	Lower	Cost
	Switch to oxy-gas	Lower	Oxygen cost, quality
Operations	Lower seed count	Higher	Quality demands
	Higher cullet proportion	Lower	Cullet availability, glass quality
	Higher pull rate	Lower	Higher temperature, shorter campaign
	Glass color/composition	Either	More energy with higher silica, color

Analytic Basis for Glass Subprogram Priorities

- Use analytic tools to identify the best opportunities for reducing energy intensity
- Set focus areas based on gap between current use and theoretical need
- Quantify potential energy savings in each focus area
- Issue solicitations and select projects as funding allows

Energy Use/Opportunity



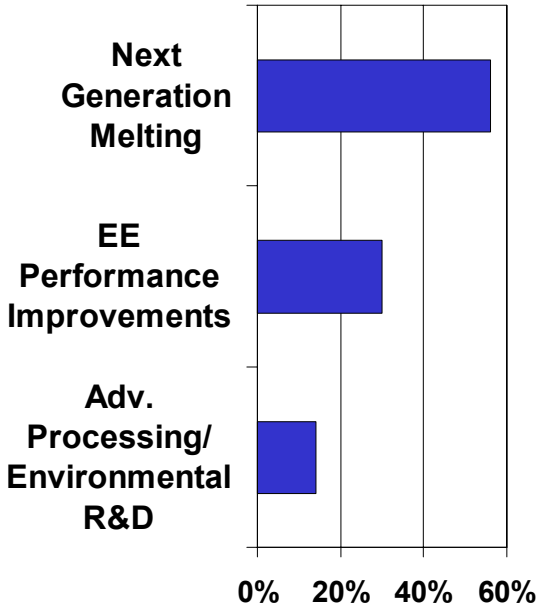
Glass Focus Areas

1. Next Generation Melting Systems
2. Energy Efficiency Performance Improvements
3. Advanced Processing and Environmental R&D

SOLICITATIONS

R&D PROJECTS

R&D Budget (FY 2004)



Summary of Glass R&D Focus Areas

Focus Areas	Goal	Timeframe and Risk
1. Next Generation Melting Systems	Dramatically reduce melting energy intensity through new technology	Long-Term High-Risk
2. Energy Efficiency Performance Improvement	Maximize energy efficiency utilizing existing plant structure	Mid-Term Medium-Risk
3. Advanced Processing and Environmental R&D	Improve production efficiency/yield and reduce environmental impact	Mid-Term Medium-Risk

Focus Area #1: Next Generation Melting Systems

Barrier-Pathway Approach and Project Selection

Barriers ➡ *Pathways* ➡ *Metrics*

- Reduce energy use without reducing glass quality and production rate
- Reduce need for additional refining and conditioning
- Reduce risk of scale-up to >500 t/day plant size

- Demonstrate alternative approaches to melting and evaluate at pilot-scale
- Validate achievement of technical targets and required integration with refining/ conditioning and other plant systems
- Expand industry collaboration for broader commercial adoption

Metric	2020
Energy Savings	26 Trillion Btu
Cost Savings	$73 million
Carbon Reduction	0.3 MMTCe

- **Solicited for advanced melting concepts in 2002**
- **Selected two projects following merit review**
  - **Submerged Combustion Melting**
  - **High-Intensity Plasma Melting**

Next Generation Melting Systems Example

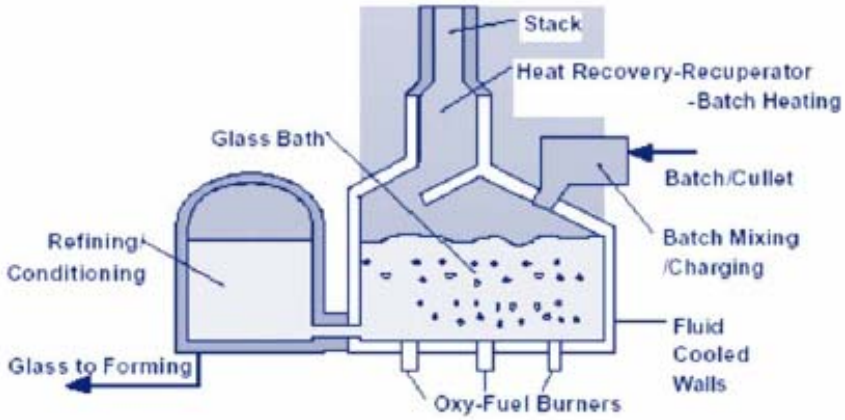
Submerged Combustion Melting (CPS #14231)

Technology Description:

- New glass melting technique employing direct heat transfer and turbulent mixing through submerged oxy-fuel burners

- **Benefits**
  - Up to 23% energy savings and associated combustion-related emissions
  - Significant reduction in capital costs and increased operational efficiency
  - Up to 50% reduction in NOx emissions
  - Up to 80% reduction in refractory usage

- **Status**
  - Melter modeling and design underway
  - Pilot-scale fabrication planned for FY05 (subject to availability of funding)

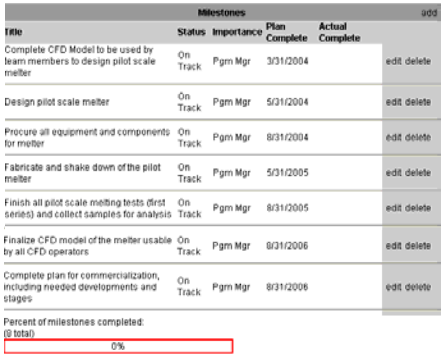


Partners: Gas Technology Institute, Corning, PPG Industries, Owens Corning, Schott Glass Technologies, Johns Manville, CertainTeed, Combustion Tec/Eclipse, Praxair, Fluent, A.C. Leadbetter and Son, NYSERDA

Next Generation Melting Systems Management by Milestone

- **ITP Milestones (CPS #14231)**

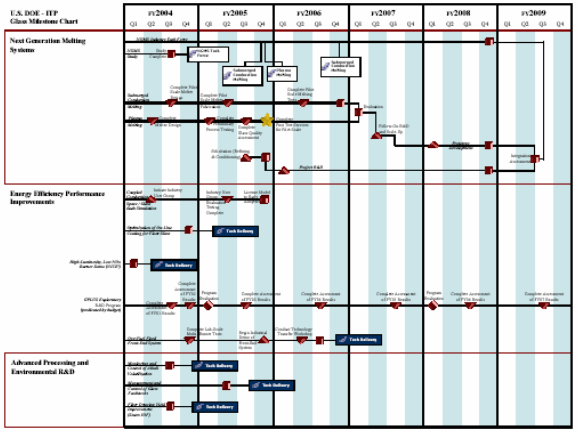
May 04	Design pilot scale melter
May 05	Fabricate and shake down pilot scale melter
May 06	Finish melting tests and analysis
Aug 06	Complete commercialization planning



Milestones					add
Title	Status	Importance	Plan Complete	Actual Complete	
Complete CFD Model to be used by team members to design pilot scale melter	On Track	Pgm Mgr	3/31/2004		edit delete
Design pilot scale melter	On Track	Pgm Mgr	5/31/2004		edit delete
Procure all equipment and components for melter	On Track	Pgm Mgr	8/31/2004		edit delete
Fabricate and shake down of the pilot melter	On Track	Pgm Mgr	5/31/2005		edit delete
Finish all pilot scale melting tests (first series) and collect samples for analysis	On Track	Pgm Mgr	8/31/2005		edit delete
Finalize CFD model of the melter usable by all CFD operators	On Track	Pgm Mgr	8/31/2006		edit delete
Complete plan for commercialization, including needed developments and stages	On Track	Pgm Mgr	8/31/2006		edit delete

Percent of milestones completed:
(0 total)
0%

Project Milestones in CPS



Linked with MYPP Milestones

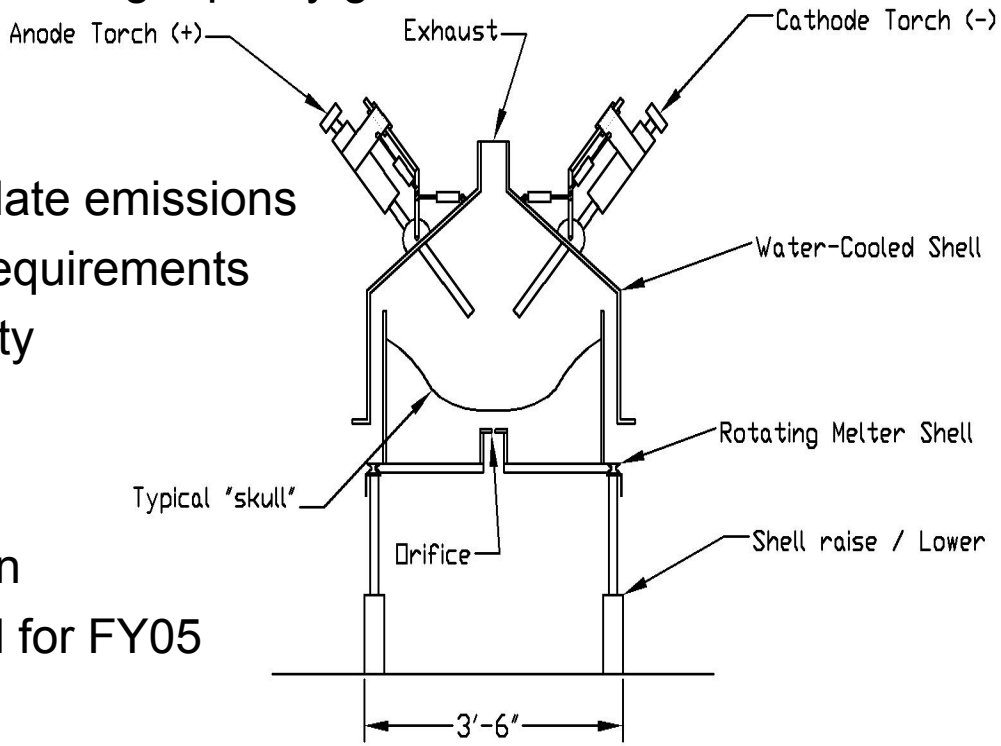
Next Generation Melting Systems Example

High-Intensity Plasma Melting (CPS #14232)

Technology Description:

- Modular, electricity-based melter design utilizing dual-torch plasma arc melting technology for production of high quality glass

- **Benefits**
  - Up to 40% energy savings
  - Reduced CO_2, NO_X, and particulate emissions
  - Lower capital costs and space requirements
  - Improved operability and flexibility
  - Reduction in refractory usage
- **Status**
  - Melter design nearing completion
  - Prototype melter testing planned for FY05



Partners: Plasmelt Glass Technologies, Johns Manville, Advanced Glassfiber Yarns

Focus Area #2: Energy Efficiency Performance Improvements

Barrier-Pathway Approach and Project Selection

Barriers → *Pathways* → *Metrics*

- Energy requirements of current glass compositions
- Limitations of existing simulation tools and materials
- Ineffective use of waste furnace heat
- Lack systems to optimize combustion heat transfer

- Continue development of existing projects and award new projects for advanced, energy-efficient process technology
- Demonstrate and evaluate advanced technology
- Integrate technological advances into existing glass plant operations

Metric	2020
Energy Savings	17 trillion Btu
Cost Savings	$67 million
Carbon Reduction	0.25 MMTCe

- **Select high energy impact efficiency projects as funding permits**
- **One project funded in FY 2003: Oxy-Fuel Fired Front-End System**

Energy Efficiency Performance Improvement Projects

- Oxy-Fuel Fired Front-End System
- Coupled Combustion Space/Glass Bath Simulation
- High-Luminosity, Low-NOx Burner Demonstration (NICE3)
- Optimization of On-Line Coating for Float Glass
- GPLUS Exploratory Research Program

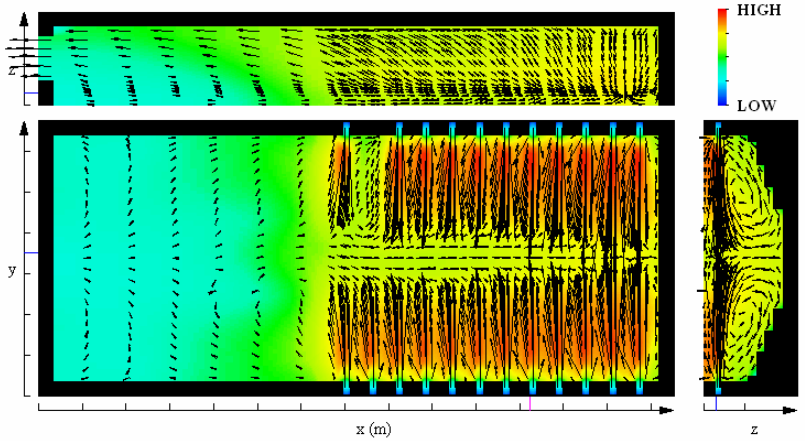
EE Performance Improvements Example

Coupled Combustion Space/Glass Bath Simulation (CPS #1025)

Technology Description:

- An innovative, three-dimensional, glass melting furnace simulation model that provides a more accurate representation of the entire melting process by coupling the combustion space with the glass batch and the glass bath

- **Benefits**
  - Improved energy and production efficiency
  - Reduced emissions
  - Advance design capabilities
- **Status**
  - Final version of code complete
  - Validation studies continuing
  - Establishing user group



Partners: Argonne National Laboratory, Techneglas, Libbey, Osram Sylvania, Owens Corning, Visteon, Purdue University, and Mississippi State University

Focus Area #3: Advanced Processing and Environmental R&D

Barrier-Pathway Approach and Project Selection

Barriers

- Lack robust, cost-effective sensing capability
- Lack sufficient understanding of physical processes
- Lack predictive and analytic tools for fabrication and emissions
- Regulatory risk for environmental improvements

Pathways

- Continue development of existing projects and award new projects to increase glassmaking productivity
- Demonstrate and evaluate advanced technology
- Integrate technological advances into existing glass plant operations

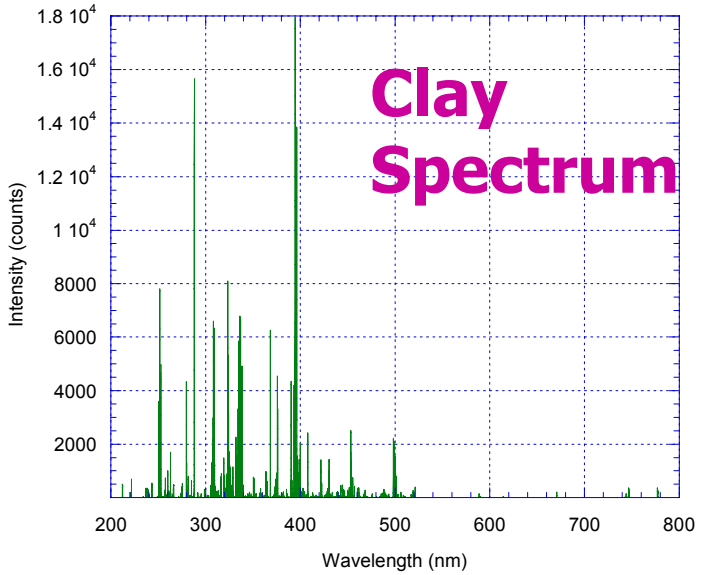
Metrics

Metric	2020
Energy Savings	6 trillion Btu
Cost Savings	$25 million
Carbon Reduction	0.09 MMTCe

- **Select high energy and productivity impact projects as funding permits**
- **No projects funded in FY 2003, activities continue**

Advanced Processing and Environmental R&D Projects

- Measurement and Control of Glass Feedstocks
- Monitoring and Control of Alkali Volatilization
- Fiber Drawing Yield Improvement (States IOF)



Glass Subprogram Management Resources

- **Headquarters Program Management:**
  - Glass Technology Lead and Industry Liaison: Elliott Levine
  - Guidance and feedback from expert consultants
    - e.g., Warren Wolf, Phil Ross, Jim Shell
  - Guidance and feedback from associations
    - e.g., Glass Manufacturing Industry Council

- **Golden Field Office**
  - Project Manager: Brad Ring
  - Contract Administration
  - Financial Accounting

Subprogram Review and Assessment - Internal

- Rigorous evaluation process for program and projects:
  - Annual analysis of expected benefits (in accordance with Government Performance and Results Act) serves multiple purposes:
    - Up-front program planning and project selection
    - Benefits projection and project justification
  - Quarterly milestone review (most recently January 2004)
  - Ongoing project management by the field office
  - Commercialization planning

Subprogram Review and Assessment - External

- Annual portfolio review (most recently September 2003)
  - Open meeting
  - Formal evaluations
  - Introduce glass industry to a range of technology
- Distribution of quarterly and final reports to the glass industry

Maximizing Opportunities in ITP and EERE

Collaborating with ITP Technology Delivery Subprograms

• Allied Partnership with GMIC

• Encouraging glass industry participation in Plant-Wide Assessments

• Distributing Glass Resources CD-ROM

• Activities to accelerate commercialization and adoption

Leveraging with other ITP and EERE Programs

• R&D Projects in the following programs:
  - Industrial Materials
  - Sensors and Automation
  - States IOF
  - NICE3
  - Inventions & Innovations
  - SBIR

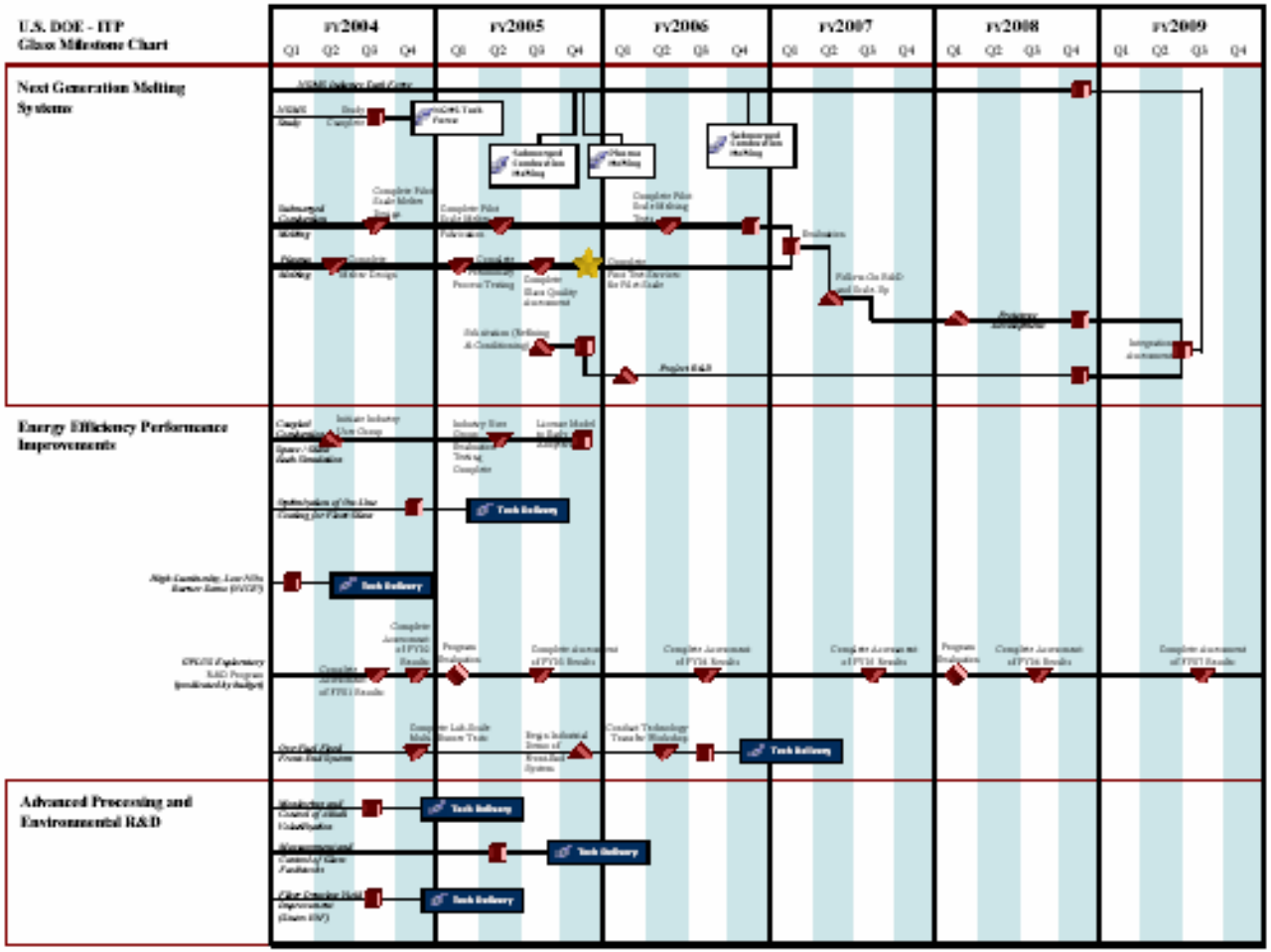
• Submitted joint glass-related topic with EERE Buildings program

• EERE Glass Review Board

Partnership Experience: Selected Highlights

- Glass Vision Published 1/96
- Technology Roadmap Workshop 4/97
- First Solicitation for Glass R&D 8/97
- GMIC Formed 9/98
- **GMIC/DOE Compact Signing 2/99**
- Next Generation Melting Workshop 2/01
- GMIC Published Technology Roadmap 4/02
- Latest Glass R&D Awards 4/03
- GMIC/DOE Allied Partnership Agreement 6/03
- 7th Annual Project Review & NREL Tour 9/03

Milestone Tracking System



Key Milestones

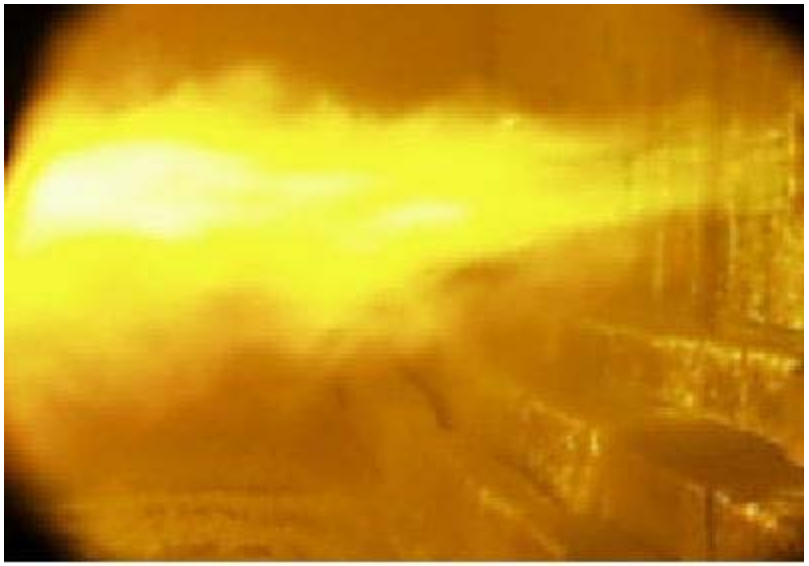
Milestone	Expected Completion
Next Generation Melting Systems	
• Complete plasma melter design	3/04
• Complete submerged combustion pilot scale design	6/04
• Complete submerged combustion pilot-scale fabrication	3/05
• Complete plasma melter glass quality assessment	6/05
• Initiate research on refining/conditioning	10/05
Energy Efficiency Performance Improvements	
• Begin transfer of results from online float glass coatings project	3/04
• Complete user group evaluation of furnace model	3/05
• Begin industrial demonstration of oxy-fuel front-end system	12/05
Advanced Processing and Environmental R&D	
• Begin transfer of results from alkali volatilization project	6/04
• Complete demonstration of glass feedstock analysis system	2/05

Accomplishments: Long History of Success

- **Oxy-Fuel Firing for Glass Furnaces**
  - Commercialized in 1990
  - Increases production rates by 10-15%
  - Reduces NOx by up to 90%
  - Over 100 commercial installations in the U.S.

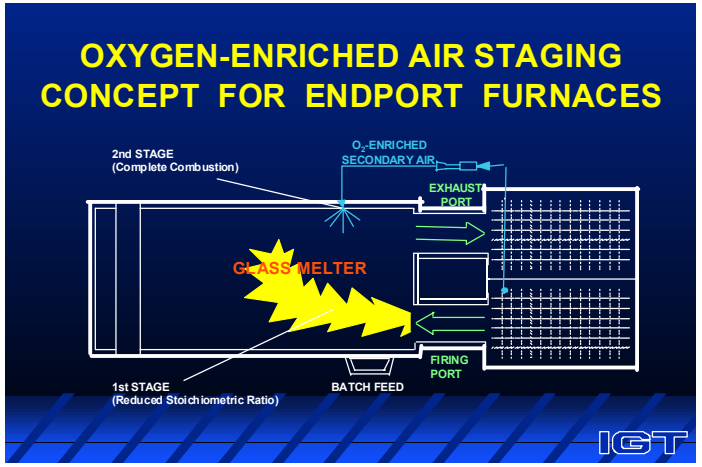
Segment	# of Oxy-Fuel Furnaces	Total # of Furnaces	Percent Oxy-Fuel
Textile Fiberglass	31	68	46%
Pressed and Blown	27	79	34%
Container	24	126	19%
Wool Fiber	12	43	28%
TV Glass	9	12	75%
Lighting	8	21	38%
Flat	2	40	5%

- **High-Luminosity, Low-NOx Burner**
  - Full-scale commercial field testing completed in two glass industry sectors
  - Impact – NOx and thermal efficiency/energy reduction
  - Commercially available

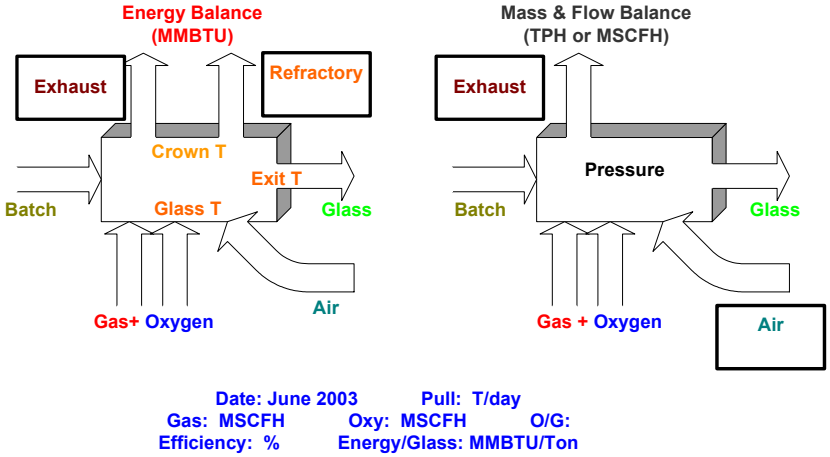


Accomplishments

- **Oxygen-Enriched Air Staging**
  - Commercialized in 1996
  - R&D 100 Award winner
  - Demonstrated NOx reductions of 35-70%
  - Over 15 commercial installations



- **Oxy-Fuel Optimization Protocol**
  - Completed in 2003
  - Provides tool set for increasing furnace efficiency
  - Results showed 5% efficiency opportunity
  - Case study about to be released

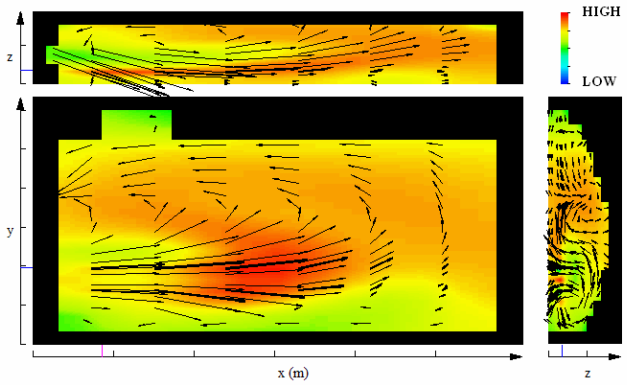


Selected FY 2003-2004 Accomplishments

- **Glass Melt Properties Database**
  - Completed in 2003
  - Improves the effectiveness of mathematical modeling
  - Impact – production and energy efficiency

Families Studied	Parameters Studied
Low-expansion borosilicate	Gas solubility
Container	Gas diffusivity
E-type textile fiberglass	Density
Float	Electric resistivity
Color TV panel	Surface properties
Wool-type insulation	Radiative conductivity
	Non-Newtonian viscosity
	Oxygen partial pressure

- **Advanced Glass Furnace Model**
  - Robust, final version of the code operational
  - Validation studies ongoing
  - Impact – energy and production efficiency



Summary

The ITP Glass Subprogram is:

- A structured, analytic-based subprogram with well-defined areas
- Achieving tangible results, significant accomplishments forthcoming
- Successfully partnering with industry
- Leveraging existing funding
- Contributing to ITP and EERE energy and strategic goals

Backup/Removed Slides

Example: Seed Content and Glass Quality

Acceptable Seed Quality by Sector

Glass Market	Seeds/Oz.	Relative Seed Quality
LCD Display		10x better than TV panel glass
TV Panel		10x better than float glass
Float/Flat		1,000 to 10,000x better than container glass
Textile Fiber		100x better than container glass
Tableware	< 2	10x better than container glass
Lighting Glass	~ 25	2x better than container glass
Container	10-20	10x better than funnel glass
TV Funnel	~ 200	2x better than wool insulation fiberglass
Insulation Fiber	~ 400	

Leveraging with ITP Crosscutting and Other EERE Programs

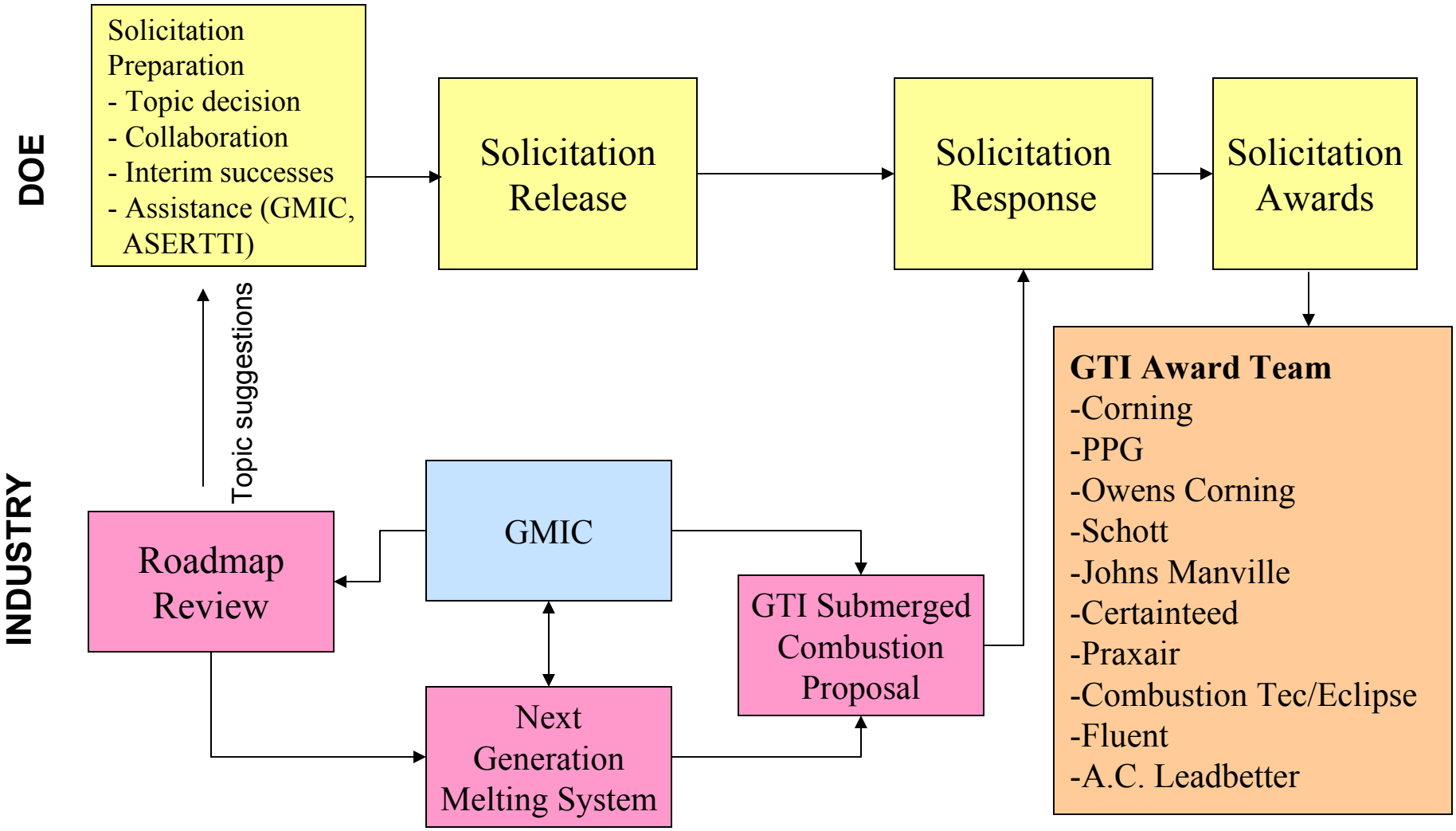
Materials	Advanced Thermoelectric Materials for Waste Heat Recovery
Sensors & Automation	Control of Natural Gas Furnaces via Flame Image Analysis
SEP	Fiber Drawing Yield Improvement
SBIR	Universal Photo-Acoustic Sensor System Optical Fiber Probe for the Measurement of High Temperatures
Inventions & Innovations	Manufacturing Ceramic Products from Waste Glass High Throughput Vacuum Processing for Innovative Uses of Glass
NICE3	Clean, Efficient Glass Production Using High-Luminosity Burners
EERE Buildings	Submitted joint glass-related topic

EERE Glass Review Board

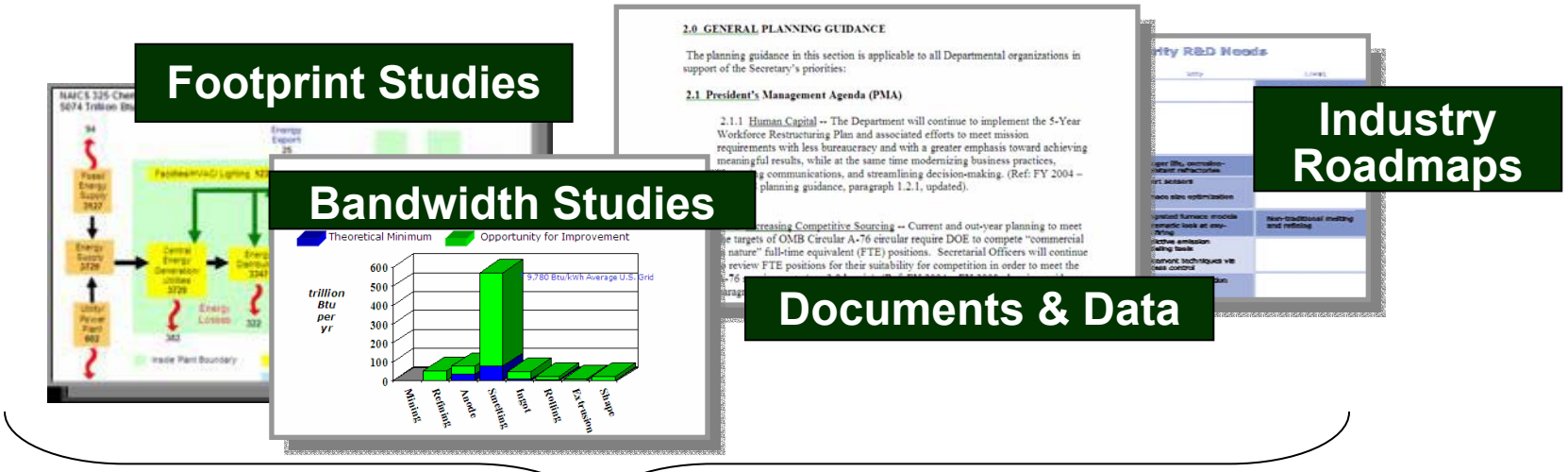
Collaborating with ITP Technology Delivery Programs

- Delivering technology through Allied Partnership with GMIC
  - Training workshops conducted
- Encouraging glass industry participation in PWAs
- Distributing Glass Resources CD-ROM
- Focusing efforts to accelerate commercialization and adoption

Example: Glass Collaboration Experience



Barrier Pathway Approach



FOCUS AREA | FOCUS AREA | FOCUS AREA | FOCUS AREA